

Final Report

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This grant was initiated in 1982. Consequently, in order to keep this report a reasonable size, only a brief outline of the work performed will be given. Further details can be found in the numerous references provided, which constitute a selected set of papers funded by the grant. The overall focus of our studies was concerned with modeling the response of the solar atmosphere to impulsive phase energization (notably by bombardment by beams of non-thermal electrons) and evaluation of the associated high-energy (notably hard X-ray) radiation signatures. Much of the work was related to the extensive database from the various instruments on the *Solar Maximum Mission*. In addition, the P.I. served on the Science Study Group for the High Energy Solar Imager (HESI) mission, leading to the development of diagnostics (e.g., spectral, spatial, and temporal variations in hard X-ray flux) that can be tested by this mission; these contributions will be published in the upcoming Study Group report and in several other contributions (Ramaty, Dennis, and Emslie 1988, *Solar Phys.*, **118**, 17; Chanan, Emslie, and Novick 1988, *Solar Phys.*, **118**, 309; Lin, Dennis, Emslie, *et al.* 1993, *Adv. Space Res.*, **13**, #9, 401; Dennis, Emslie, *et al.* 1994, AIP Conference Proceedings No. **294**, 230; Lin, Dennis, Ramaty, Emslie, Canfield and Doschek 1994, *Geophysics Monograph Series*, **84**, 283). He also participated in numerous conferences and workshops, including the authorship of three chapters in the NATO Advanced Study Institute on "The Sun - A Laboratory for Astrophysics" (ASI C-303).

Considerable effort was devoted toward understanding the relationship between impulsive phase hard X-ray emission and other (generally thermal) radiation signatures. Using work on the physics of electron beam transport in partially ionized hydrogen plasmas (Emslie 1978, *Ap. J.*, **224**, 241; Emslie 1980, *Ap. J.*, **235**, 1055; Chandrashekar and Emslie 1987, *Solar Phys.*, **107**, 83; Spicer and Emslie 1988, *Ap. J.*, **330**, 997; LaRosa and Emslie 1989, *Solar Phys.*, **120**, 343), we calculated the source term in the energy equation effected by such electron bombardment, and used it in a sophisticated numerical hydrodynamic code to construct temperature, density, and velocity profiles for the flaring atmosphere (Mariska, Emslie, and Li 1989, *Ap. J.*, **341**, 1067; Emslie, Li, and Mariska 1992, *Ap. J.*, **399**, 714). A "reality check" on these results was obtained through analytic modeling using an innovative technique based on self-similarity (Brown and Emslie 1989, *Ap. J.*, **339**, 1123). Additional work was carried out on the magnetohydrodynamic effects produced by an impulsive energy release in the corona, and on the expected hard X-ray

signature from such events (Roumeliotis and Emslie 1991, *Ap. J.*, **337**, 685) and on the effects of radiation backwarming on the chromospheric flare (Machado, Emslie, and Mauas 1984, *Astr. Ap.*, **159**, 33; Machado, Emslie, and Avrett 1989, *Solar Phys.*, **124**, 303).

"Post-processing" of the numerical data allowed us to construct synthetic data for thermal emissions, such as soft X-ray line profiles (Emslie and Alexander 1987, *Solar Phys.*, **110**, 295; Li, Emslie, and Mariska 1989, *Ap. J.*, **341**, 1075) and soft X-ray light curves (Brown and Emslie 1978, *Solar Phys.*, **110**, 305; Li and Emslie 1990, *Solar Phys.*, **129**, 113). We have extended the analysis of soft X-ray line profiles to a new concept termed the Velocity Differential Emission Measure (VDEM; Newton, Emslie, and Mariska 1995, *Ap. J.*, in press), and we intend to apply this technique to flares observed by Yohkoh. Predicted fluxes in Fe K α (Emslie, Phillips, and Dennis 1985, *Solar Phys.*, **103**, 89) and Ca XIX (Emslie 1985, *Solar Phys.*, **92**, 281) were evaluated and compared with observations (Emslie 1985, *Solar Phys.*, **103**, 103). In our work on soft X-ray/hard X-ray temporal correlations, we were able to shed light on the validity of the so-called "Neupert effect," in which the hard X-ray intensity is proportional to the time derivative of the soft X-ray flux (Li, Emslie, and Mariska 1993, *Ap. J.*, **417**, 313). A means of accounting for the apparently small footpoint areas deduced from hard X-ray/EUV correlations, while still maintaining physically acceptable beam fluxes, was established (LaRosa and Emslie 1988, *Ap. J.*, **326**, 997).

The possible forms of hard X-ray spectra in flares were assessed (Brown and Emslie 1988, *Ap. J.*, **331**, 554) and the results applied to the high-resolution spectra obtained in a 1981 balloon flight (Emslie, Coffey, and Schwartz 1989, *Solar Phys.*, **127**, 313). Various concepts for hard X-ray imaging devices were pursued with the aim of discriminating between standard paradigms (e.g., "thick-target model", "thermal model", etc.) (Campbell, Emslie, and Davis 1990, *Proc. SPIE*, **1343**, 359). A possible mechanism for hard X-ray production using proton, rather than electron, beams, was evaluated (Brown and Emslie 1985, *Ap. J.*, **295**, 648), with rather negative results. The physics of rapid fluctuations in hard X-ray events was examined (Kiplinger, Dennis, Emslie, Frost, and Orwig 1983, *Ap. J. (Letters)*, **265**, L99).

Analysis of vector magnetograph data, emphasizing projection effects and the use of integral, rather than differential, algorithms for current detection, was carried out (Wilkinson, Emslie and Gary 1989, *Solar Phys.*, **119**, 77; Wilkinson, Emslie, and Gary 1992, *Ap. J. (Letters)*, **392**, L39). The results show that active regions tend to carry no net current as a whole. Further work on current closure in the impulsive phase of solar flares has been carried out (Emslie and Hénoux 1995, *Ap. J.*, in press).